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(54) **RADIO FREQUENCY ANTENNA ARRAY WITH SPACING ELEMENT**

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(52) **U.S. Cl.**

CPC ***H01Q 1/2266*** (2013.01); ***H01Q 1/243*** (2013.01); ***H01Q 9/22*** (2013.01); ***H01Q 9/285*** (2013.01); ***H01Q 21/062*** (2013.01); ***H01Q 21/10*** (2013.01); ***H01Q 21/24*** (2013.01)

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See application file for complete search history.

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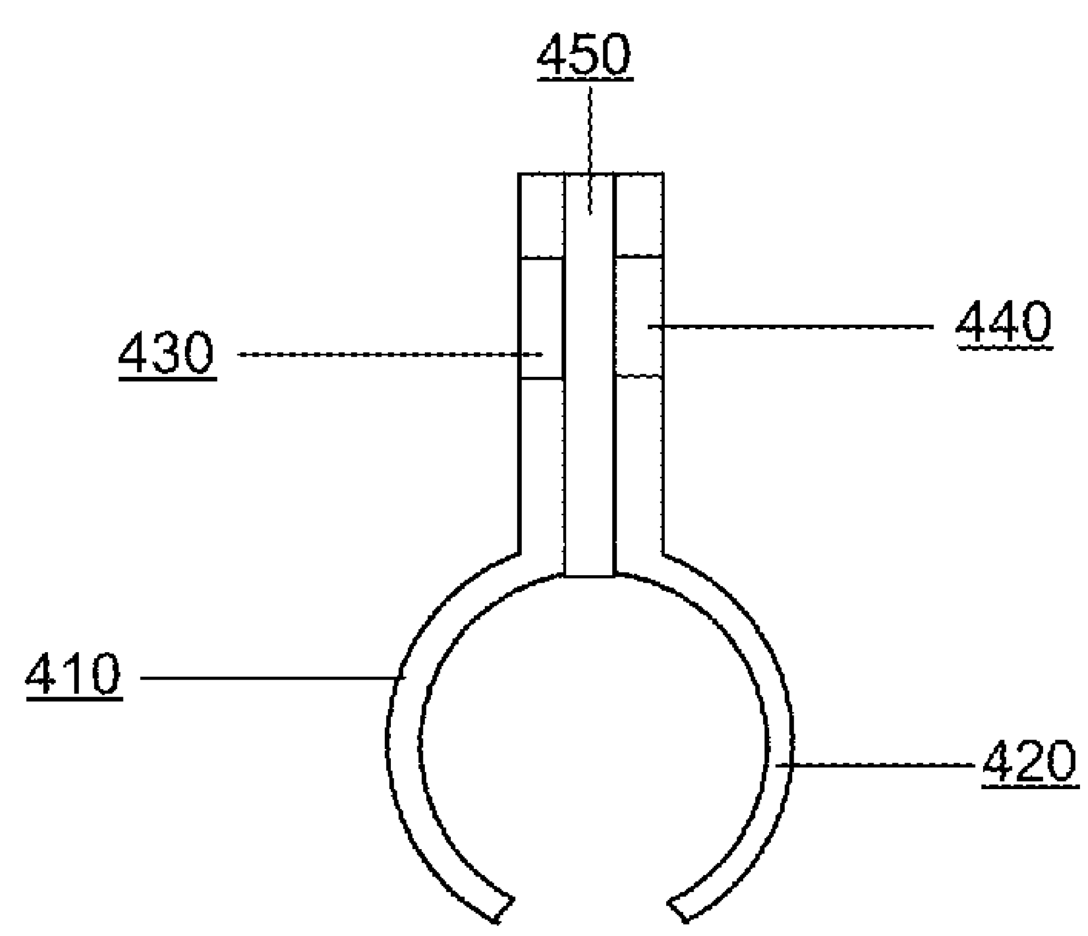
(57) **ABSTRACT**

A spacing member is positioned between a pair of antenna members. The two antenna members may be horizontally polarized or vertically polarized and positioned next to each other to provide an increased gain. The spacing element may be placed between the antenna members and have a thickness corresponding to the characteristic impedance of the antenna transmission line. The characteristic impedance may be determined based on the width of the transmission line. The spacing member may be radio-frequency (RF) transparent and may adhere to either or both of the antenna elements. The spacing member may be implemented as a plastic double sided tape or a uniform piece of plastic having one or more adhesive layers.

8 Claims, 6 Drawing Sheets



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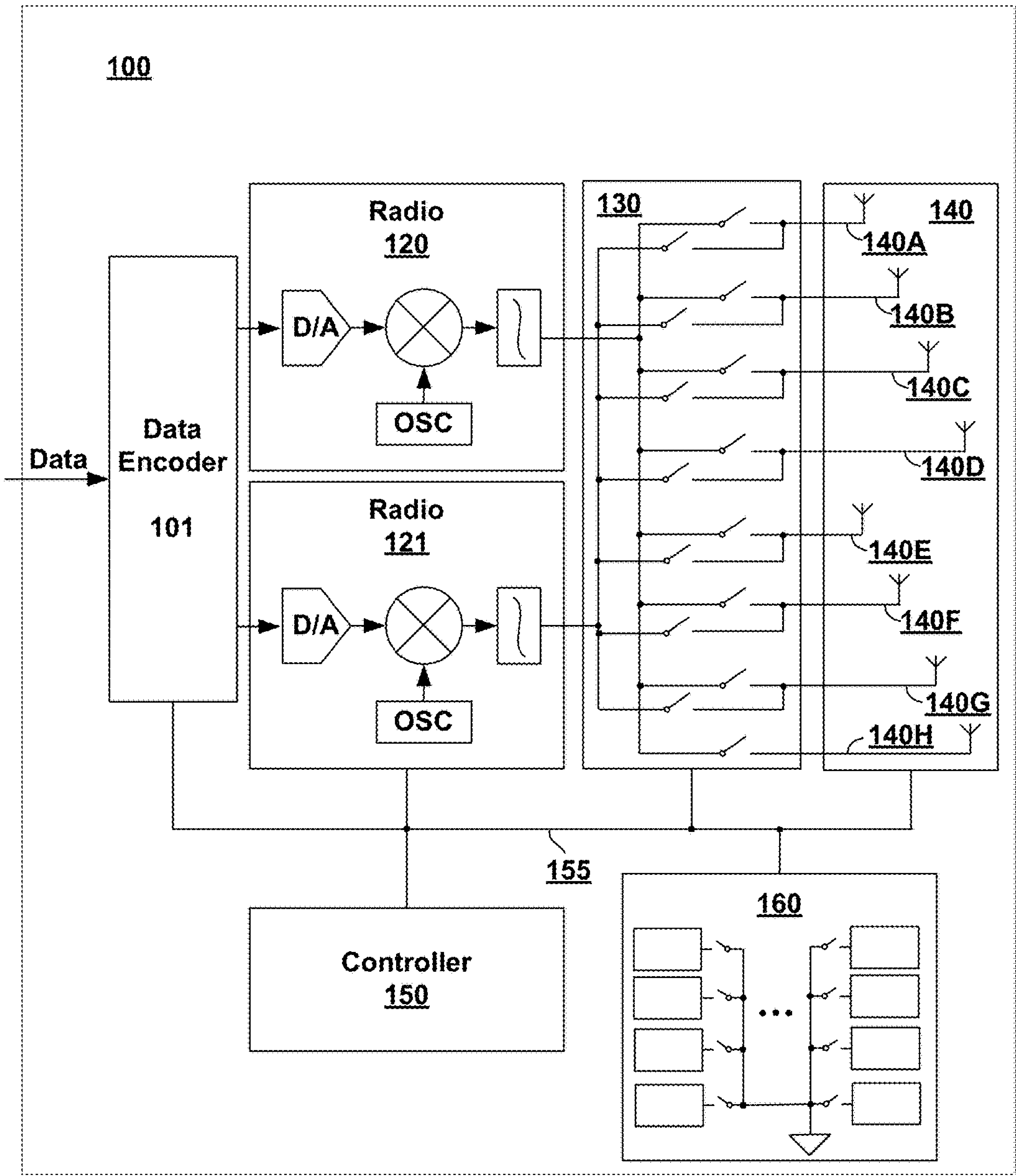
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Data
Data Encoder
101
Radio
120
D/A
OSC
Radio
121
D/A
OSC
130
140
140A
140B
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140E
140F
140G
140H
155
Controller
150
160

FIG. 1

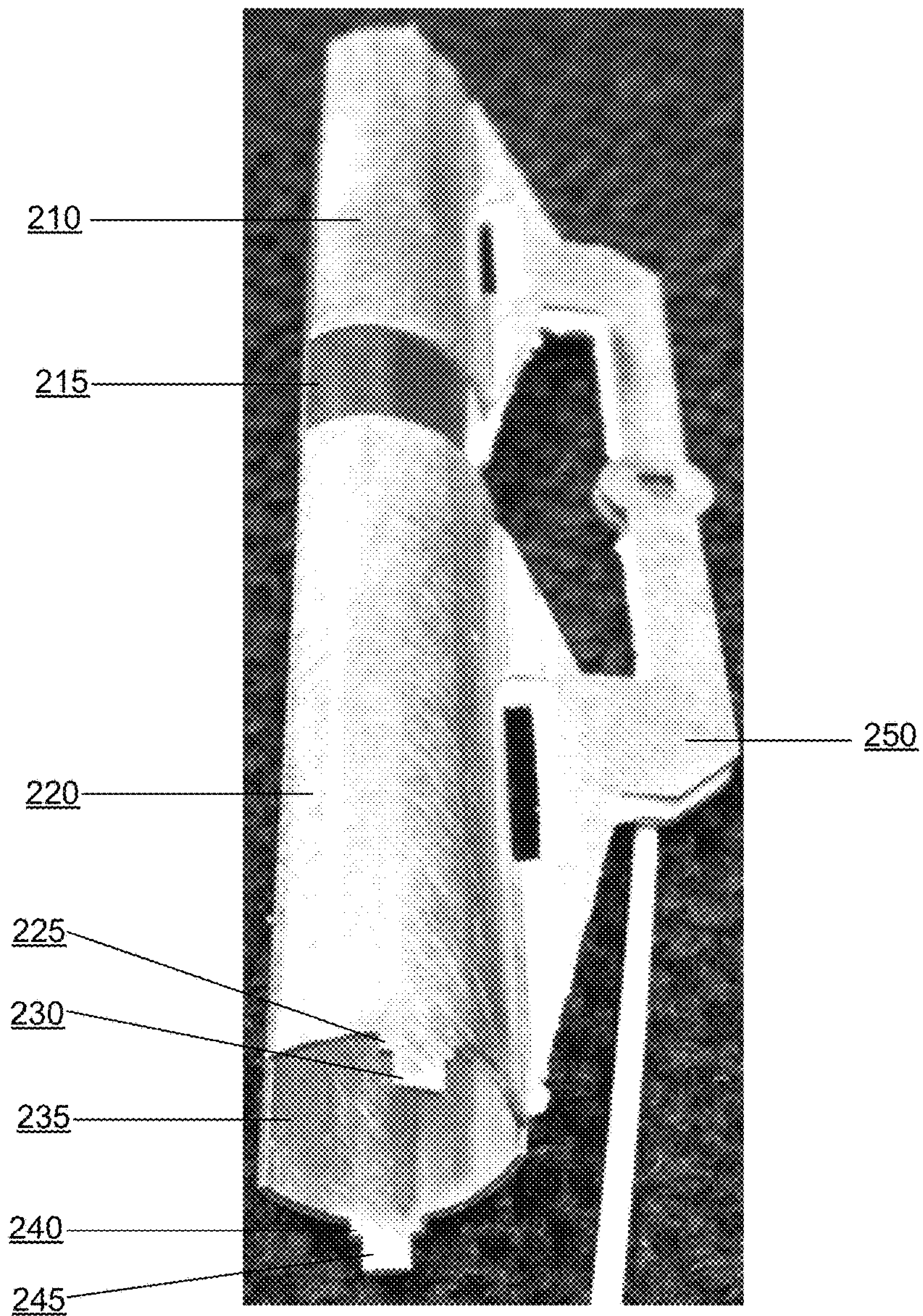

FIG. 2

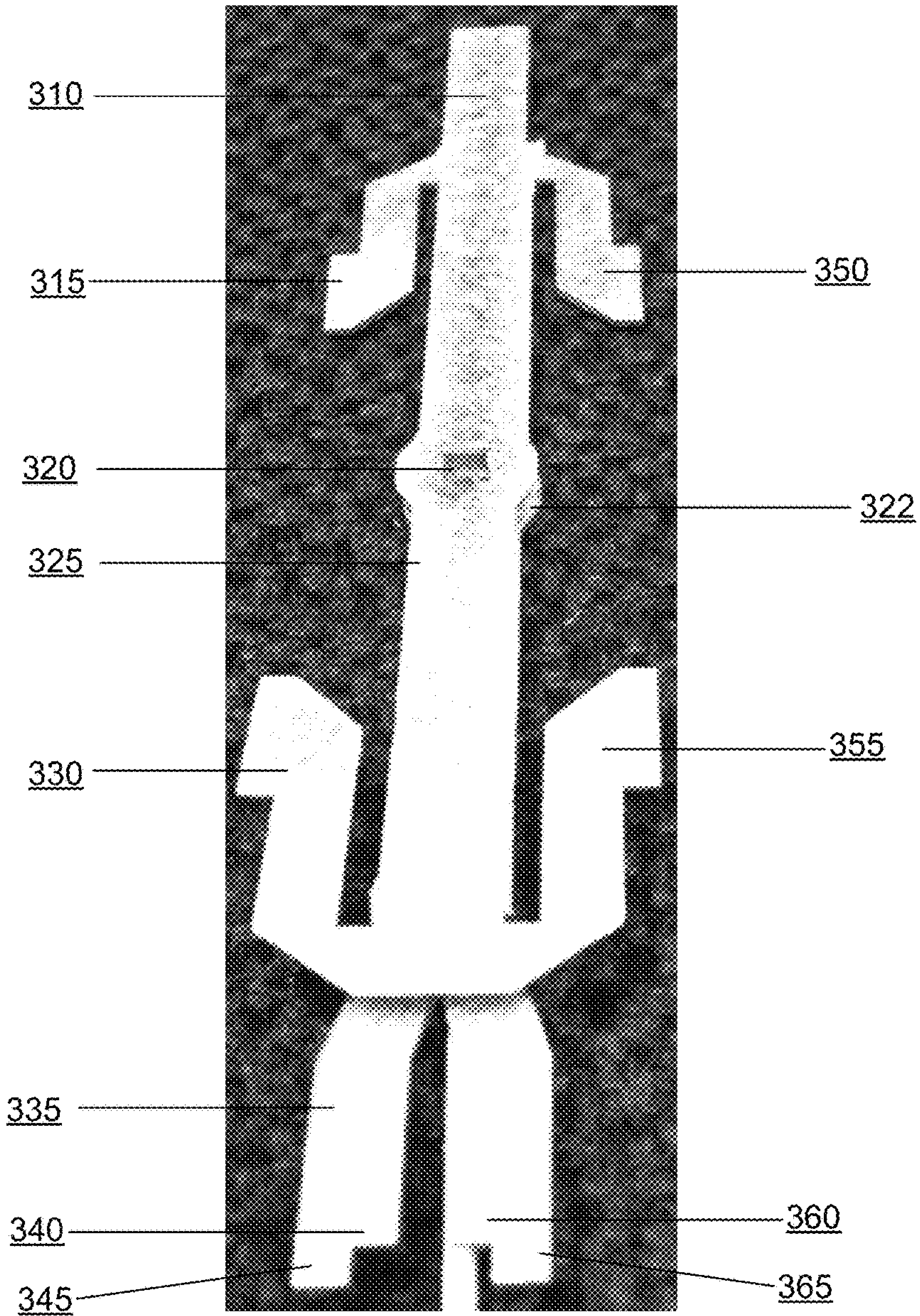

FIG. 3

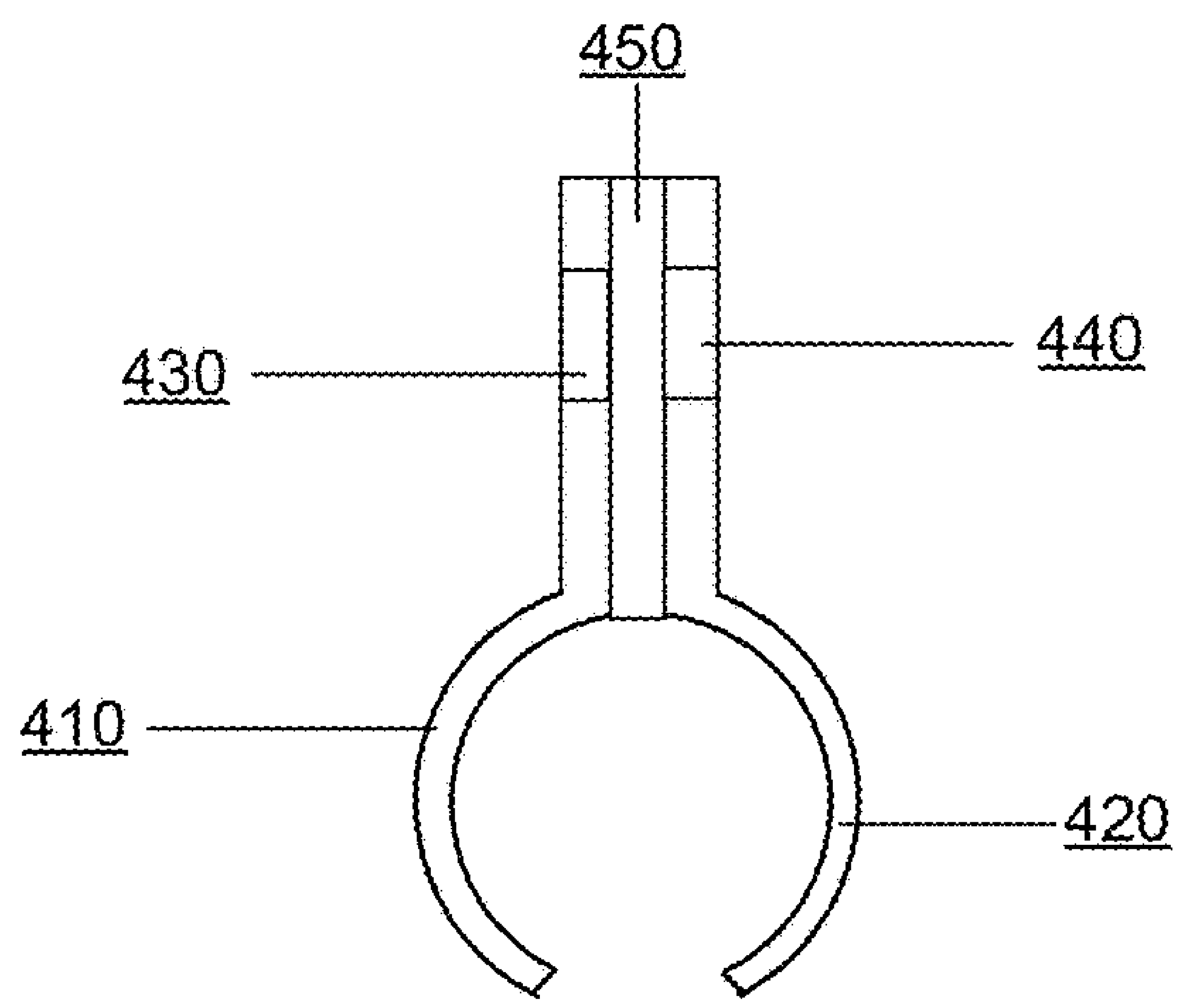

FIG. 4

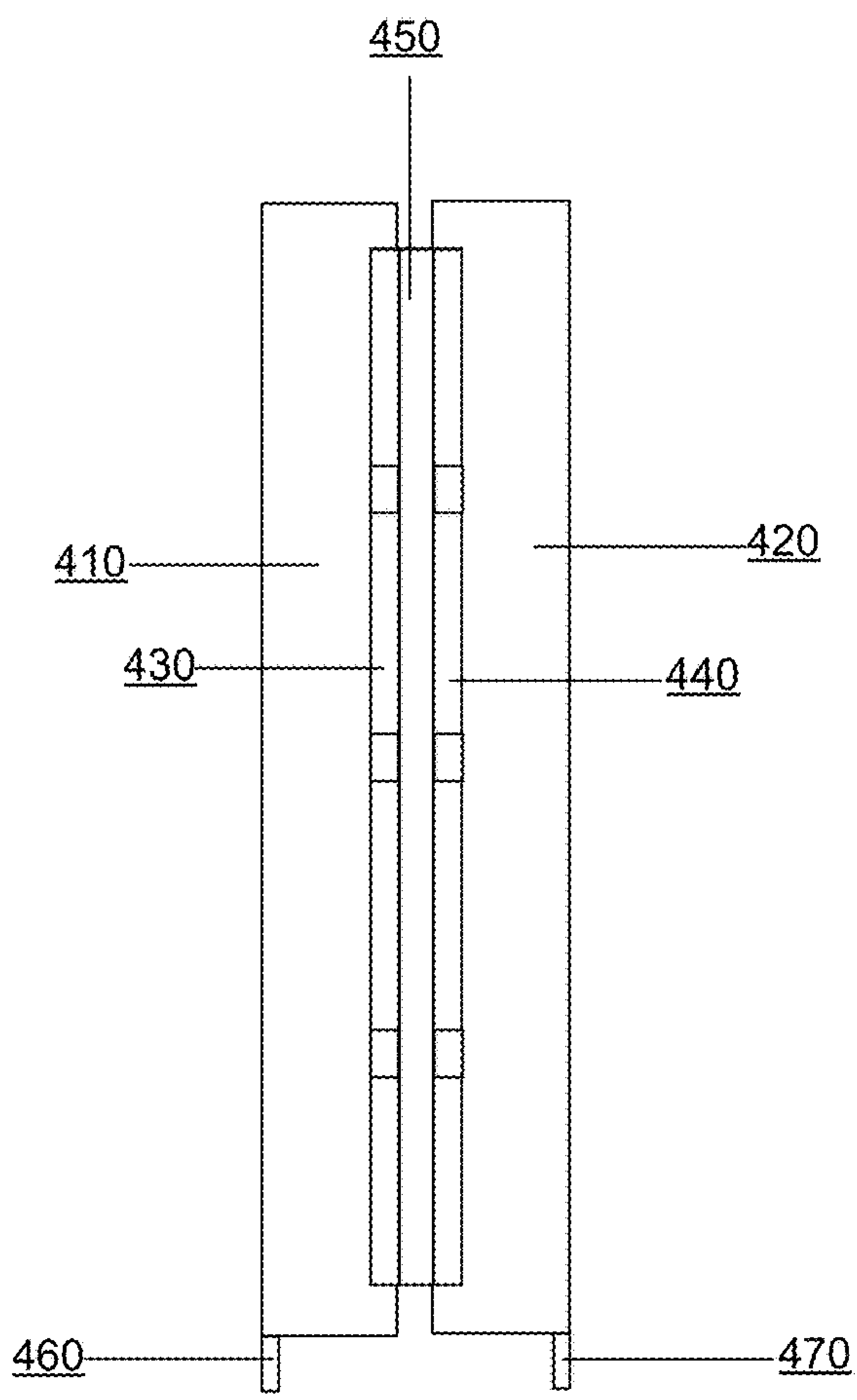

FIG. 5

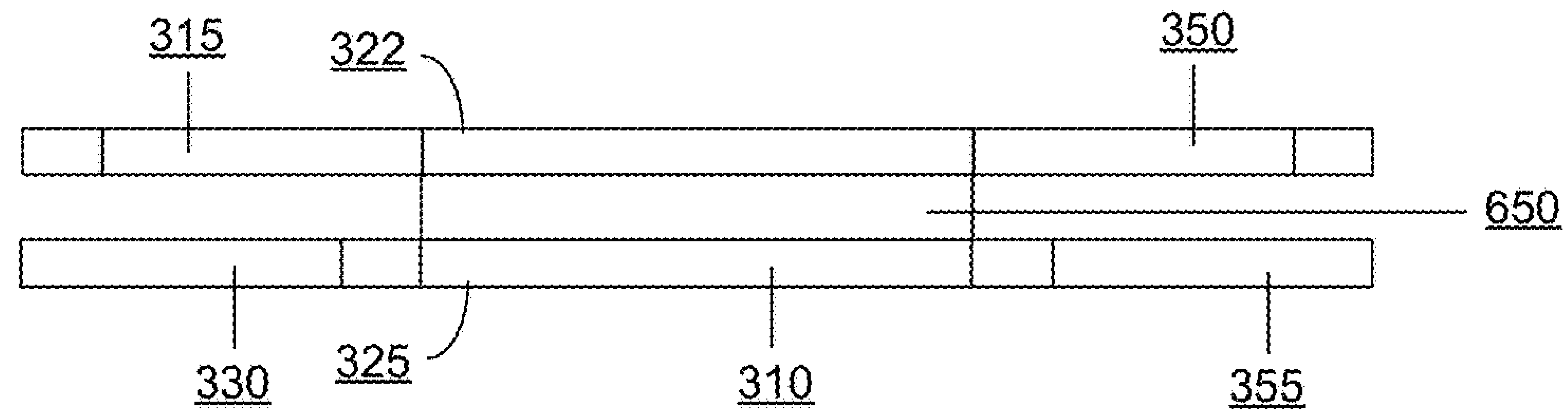

FIG. 6

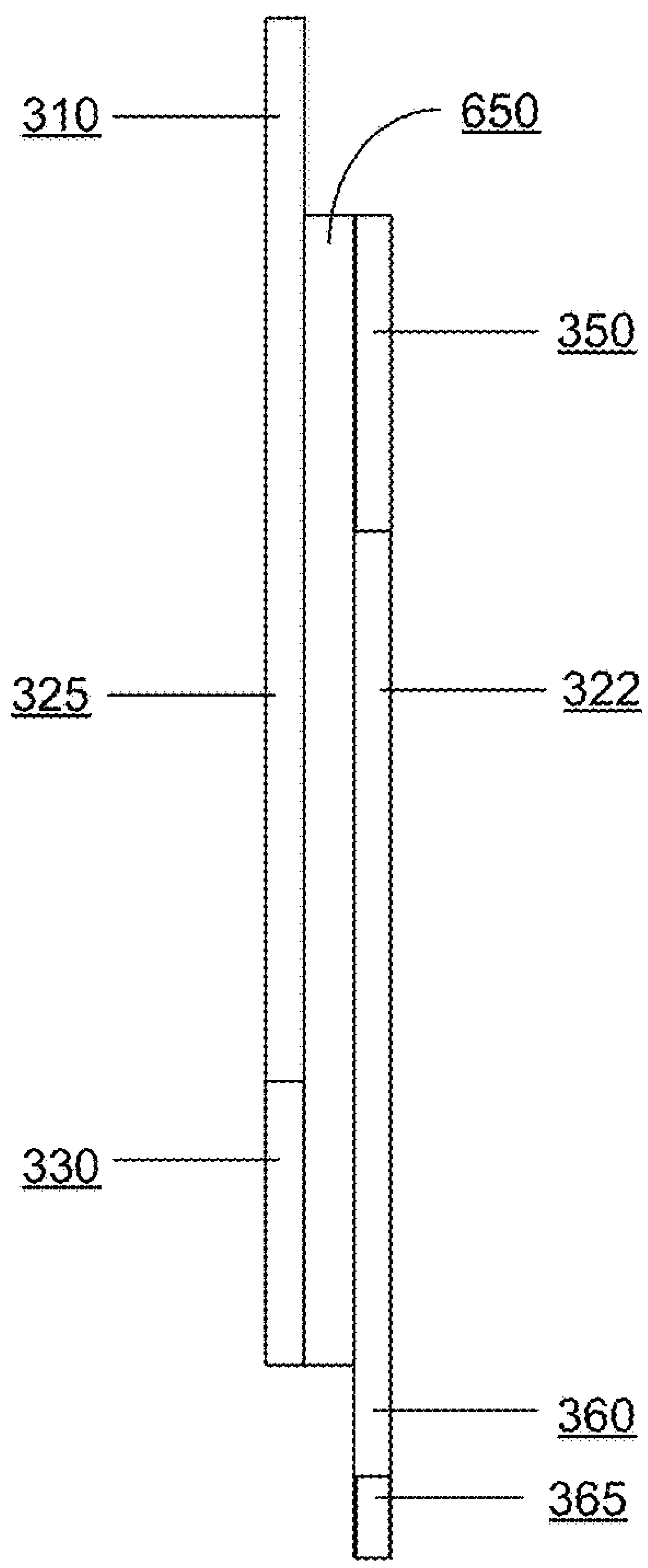

FIG. 7

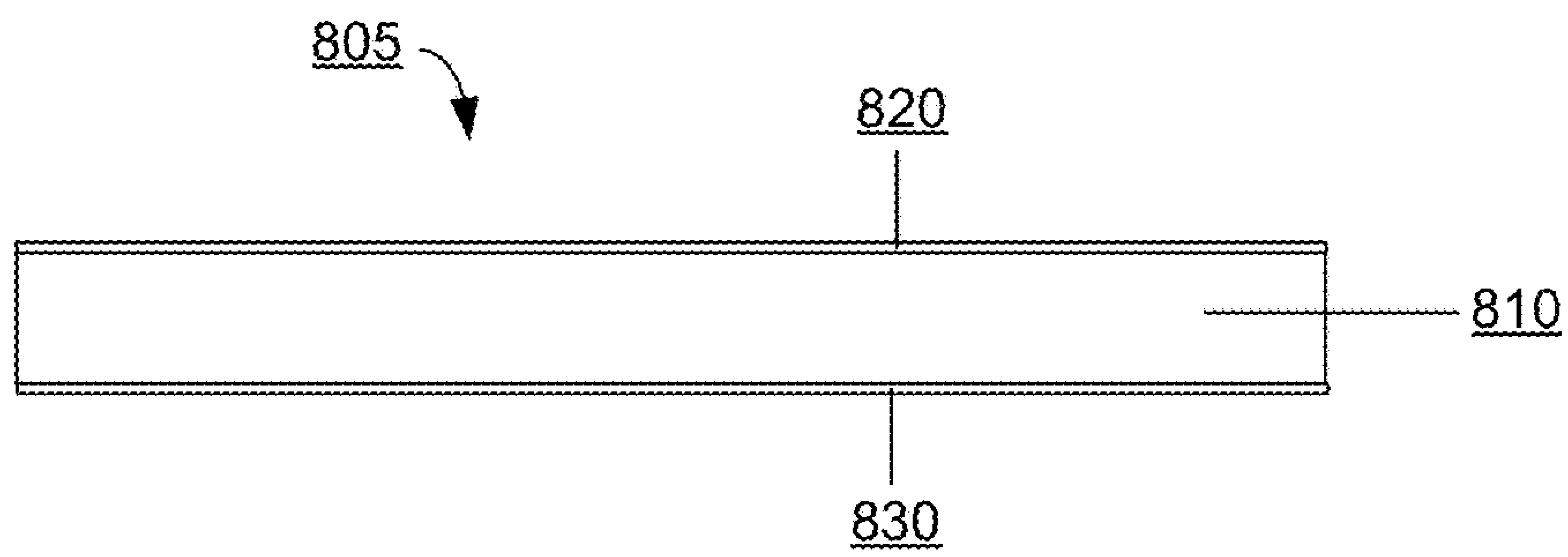

FIG. 8

FIG. 9

RADIO FREQUENCY ANTENNA ARRAY WITH SPACING ELEMENT

BACKGROUND OF INVENTION

1. Field of the Invention

The present invention generally relates to wireless communications and more particularly to changing radio frequency (RF) emission patterns with respect to one or more antenna arrays.

2. Description of the Prior Art

In wireless communications systems, there is an ever-increasing demand for higher data throughput and a corresponding drive to reduce interference that can disrupt data communications. For example, a wireless link in an Institute of Electrical and Electronic Engineers (IEEE) 802.11 network may be susceptible to interference from other wireless access points and stations, radio transmitting devices in the vicinity of the network, and changes or disturbances in the wireless link environment between an access point and remote receiving node. In some instances, the interference may degrade the wireless link thereby forcing communication at a lower data rate. The interference may, in some instances, be sufficiently strong as to disrupt the wireless link altogether.

One solution is to utilize a diversity antenna scheme. In such a solution, a data source is coupled to two or more physically separated omnidirectional antennas. An access point may select one of the omnidirectional antennas by which to maintain a wireless link. Because of the separation between the omnidirectional antennas, each antenna experiences a different signal environment and corresponding interference level with respect to the wireless link. A switching network couples the data source to whichever of the omnidirectional antennas experiences the least interference in the wireless link.

Notwithstanding, many high-gain antenna environments still encounter—or cause—electromagnetic interference (EMI). This interference may be encountered (or created) with respect to another nearby wireless environments (e.g., between the floors of an office building or hot spots scattered amongst a single room). In some instances, the mere operation of a power supply or electronic equipment can create electromagnetic interference.

One solution to combat electromagnetic interference is to utilize shielding in or proximate an antenna enclosure. Shielding a metallic enclosure is imperfect, however, because the conductivity of all metals is finite. Because metallic shields have less than infinite conductivity, part of the field is transmitted across the boundary and supports a current in the metal. The amount of current flow at any depth in the shield and the rate of decay are governed by the conductivity of the metal, its permeability, and the frequency and amplitude of the field source.

With interference present in most environments, it is desirable to have a low-cost and effective solution to providing an antenna apparatus with reduced interference.

SUMMARY OF THE INVENTION

The presently claimed invention utilizes a spacing member positioned between antenna members. Two associated antenna members may be positioned next to each other to provide an increased gain. The spacing element may be placed between the antenna members and have a thickness related to the characteristic impedance of the antenna transmission line. The characteristic impedance may be determined based on the width of the transmission line. The spacing member may be radio-frequency (RF) transparent and may adhere to either or both of the antenna elements. The spacing member may include a plastic double sided tape, a uniform piece of plastic having one or more adhesive layers, or some other RF transparent material.

An embodiment of a wireless device may include an antenna array and a spacer element. The antenna array may include a plurality of antenna elements to generate a substantially omnidirectional radiation pattern. Each of the plurality of antenna elements may include a first antenna member and a second antenna member. The spacer element may be displaced between the first antenna member and the second antenna member.

BRIEF DESCRIPTION OF DRAWINGS

FIG. **1** illustrates a wireless MIMO antenna system having multiple antennas and multiple radios.

FIG. **2** illustrates a horizontally polarized antenna member pair for mounting on a printed circuit board.

FIG. **3** illustrates a vertically polarized antenna member pair for mounting on a printed circuit board.

FIG. **4** illustrates a top view of a horizontally polarized antenna member pair.

FIG. **5** illustrates a rear view of a horizontally polarized antenna member pair.

FIG. **6** illustrates a top view of a vertically polarized antenna member pair.

FIG. **7** illustrates a side view of a vertically polarized antenna member pair.

FIG. **8** illustrates a side view of a spacing member having an upper and lower adhesive layer.

FIG. **9** illustrates a side view of an adhesive tape spacing member.

DETAILED DESCRIPTION

Embodiments of the present invention implement a spacing member positioned between a pair of antenna members. The two antenna members may be horizontally polarized or vertically polarized and positioned next to each other to provide an increased gain. The spacing element may be placed between the antenna members and have a thickness corresponding to the characteristic impedance of the antenna transmission line. The characteristic impedance may be determined based on the width of the transmission line. The spacing member may be radio-frequency (RF) transparent and may adhere to either or both of the antenna elements. The spacing member may be implemented as a plastic double sided tape or a uniform piece of plastic having one or more adhesive layers. The antenna member pair having the spacing member may be used in a wireless antenna system.

FIG. **1** illustrates a wireless MIMO antenna system having multiple antennas and multiple radios. The wireless MIMO antenna system **100** may be representative of a transmitter and/or a receiver such as an 802.11 access point or an 802.11 receiver. System **100** may also be representative of a set-top box, a laptop computer, television, Personal Computer Memory Card International Association (PCMCIA) card, Voice over Internet Protocol (VoIP) telephone, or handheld gaming device.

Wireless MIMO antenna system **100** may include a communication device for generating a radio frequency (RF) signal (e.g., in the case of transmitting node). Wireless MIMO antenna system **100** may also or alternatively receive data from a router connected to the Internet. Wireless MIMO antenna system **100** may then transmit that data to one or more of the remote receiving nodes. For example, the data may be video data transmitted to a set-top box for display on a television or video display.

The wireless MIMO antenna system **100** may form a part of a wireless local area network (e.g., a mesh network) by enabling communications among several transmission and/or receiving nodes. Although generally described as transmitting to a remote receiving node, the wireless MIMO antenna system **100** of FIG. **1** may also receive data subject to the presence of appropriate circuitry. Such circuitry may include but is not limited to a decoder, down conversion circuitry, samplers, digital-to-analog converters, filters, and so forth.

Wireless MIMO antenna system **100** includes a data encoder **101** for encoding data into a format appropriate for transmission to the remote receiving node via the parallel radios **120** and **121** illustrated in FIG. **1**. While two radios are illustrated in FIG. **1**, additional radios or RF chains may be utilized. Data encoder **101** may include data encoding elements such as direct sequence spread-spectrum (DSSS) or Orthogonal Frequency Division Multiplex (OFDM) encoding mechanisms to generate baseband data streams in an appropriate format. Data encoder **101** may include hardware and/or software elements for converting data received into the wireless MIMO antenna system **100** into data packets compliant with the IEEE 802.11 format. Such software elements may be embedded in memory or other non-transitory computer readable storage media and coupled to appropriate processing components. In some instances, the appropriate conversion elements may be implemented in the context of a hardware element such as an application specific processor.

Radios **120** and **121** as illustrated in FIG. **1** include transmitter or transceiver elements configured to upconvert the baseband data streams from the data encoder **101** to radio signals. Radios **120** and **121** thereby establish and maintain the wireless link. Radios **120** and **121** may include direct-to-RF upconverters or heterodyne upconverters for generating a first RF signal and a second RF signal, respectively. The first and second RF signals are generally at the same center frequency and bandwidth but may be offset in time or otherwise space-time coded.

Wireless MIMO antenna system **100** further includes a circuit (e.g., switching network) **130** for selectively coupling the first and second RF signals from the parallel radios **120** and **121** to an antenna apparatus **140** having multiple antenna elements **140**A-H. Antenna elements **140**A-H may include individually selectable antenna elements such that each antenna element **140**A-H may be electrically selected (e.g., switched on or off). By selecting various combinations of the antenna elements **140**A-H, the antenna apparatus **140** may form a "pattern agile" or reconfigurable radiation pattern. If certain or substantially all of the antenna elements **140**A-H are switched on, for example, the antenna apparatus **140** may form an omnidirectional radiation pattern. Through the use of MIMO antenna architecture, the pattern may include both vertically and horizontally polarized energy, which may also be referred to as diagonally polarized radiation. Alternatively, the antenna apparatus **140** may form various directional radiation patterns, depending upon which of the antenna elements **140**A-H are turned on.

The RF switches within circuit **130** may be PIN diodes, gallium arsenide field-effect transistors (GaAs FETs), or virtually any RF switching device. The PIN diodes comprise single-pole single-throw switches to switch each antenna element either on or off (i.e., couple or decouple each of the antenna elements to the radios **120** and **121**). A series of control signals may be applied via a control bus **155** to bias each PIN diode. With the PIN diode forward biased and conducting a DC current, the PIN diode switch is on, and the corresponding antenna element is selected. With the diode reverse biased, the PIN diode switch is off. In some embodiments, one or more light emitting diodes (LEDs) may be included in the coupling network as a visual indicator of which of the antenna elements is on or off. An LED may be placed in circuit with the PIN diode so that the LED is lit when the corresponding antenna element is selected.

Further, the antenna apparatus may include switching at RF as opposed to switching at baseband. Switching at RF means that the communication device requires only one RF up/downconverter. Switching at RF also requires a significantly simplified interface between the communication device and the antenna apparatus. For example, the antenna apparatus provides an impedance match under all configurations of selected antenna elements, regardless of which antenna elements are selected.

Wireless MIMO antenna system **100** includes pattern shaping elements **160**. Pattern shaping elements **160** in FIG. **1** extend from a printed circuit board. The pattern shaping elements may include directors and reflectors selectively connected to ground using, for example, a PIN diode. Directors may include passive elements that constrain the directional radiation pattern, for example, to increase the gain of the antenna member pair. Pattern shaping elements such as reflectors and directors are generally known in the art. The reflectors and directors may be metal objects having any shape and placed near an antenna array such as an antenna member pair mounted on a printed circuit board.

Wireless MIMO antenna system **100** may also include a controller **150** coupled to the data encoder **101**, the radios **120** and **121**, the circuit **130**, and pattern shaping elements **160** via a control bus **155**. The controller **150** may include hardware (e.g., a microprocessor and logic) and/or software elements to control the operation of the wireless MIMO antenna system **100**.

The controller **150** may select a particular configuration of antenna elements **140**A-H that minimizes interference over the wireless link to the remote receiving device. If the wireless link experiences interference, for example due to other radio transmitting devices, or changes or disturbances in the wireless link between the wireless MIMO antenna system **100** and the remote receiving device, the controller **150** may select a different configuration of selected antenna elements **140**A-H via the circuit **130** to change the resulting radiation pattern and minimize the interference. Controller **150** may also select one or more pattern shaping elements **160**. For example, the controller **150** may select a configuration of selected antenna elements **140**A-H and pattern shaping elements **160** corresponding to a maximum gain between the wireless system **100** and the remote receiving device. Alternatively, the controller **150** may select a configuration of selected antenna elements **140**A-H and pattern shaping elements **160** corresponding to less than maximal gain, but corresponding to reduced interference in the wireless link.

Controller **150** may also transmit a data packet using a first subgroup of antenna elements **140**A-H coupled to the radio **120** and simultaneously send the data packet using a second group of antenna elements **140**A-H coupled to the radio **121**. Controller **150** may change the substrate of antenna elements **140**A-H coupled to the radios **120** and **121** on a packet-by-packet basis. Methods performed by the controller **150** with respect to a single radio having access to multiple antenna elements are further described in, for example, U.S. patent publication number US 2006-0040707 A1. These methods are also applicable to the controller **150** having control over multiple antenna elements and multiple radios.

FIG. **2** illustrates an antenna element (e.g., a dipole) for emitting a horizontally polarized radiation pattern for mounting on a printed circuit board. The antenna element illustrated in FIG. **2** includes a first antenna member and a second antenna member. The first antenna member includes an upper portion **210** and a lower portion **220**. The second antenna member also includes an upper portion **215** and a lower portion **235**. The antenna elements are connected at an RF feed point **250**. When connected together, the first antenna member and second antenna member form an antenna member pair having a barrel-type shape with a slit near the middle of the structure. The antenna member pair of FIG. **2** may transmit a radiation pattern having a frequency of about 5.0 GHZ in compliance with IEEE 802.11n.

The horizontally polarized antenna member pair of FIG. **2** may be mounted to the surface of a PCB. Antenna member lower portions **220** and **235** include tabs **230** and **245**, respectively. The tabs are constructed to fit into a printed circuit board and may be secured via solder. Above each tab on lower portions **220** and **235** are shoulders **225** and **240**, respectively. The shoulder is designed to maintain a spacing of each antenna lower portion above the printed circuit board.

An RF signal may be fed to the horizontally polarized antenna member pair of FIG. **2** via connector **250**. Connector **250** is formed by bending a tab from antenna member **210** into an aperture of antenna element **215**, and soldering the connection between the elements.

FIG. **3** illustrates a vertically polarized antenna member pair for mounting on a printed circuit board. The dipole of FIG. **3** includes a first antenna member **325** and a second antenna member **322**. The first antenna member includes a first end **310** and a second end having two finger elements **330** and **355**. The second antenna member has finger elements which are about the same as the first antenna member. The antenna members are connected together to align along their central axis such that the second antenna member is upside down with respect to the first antenna member. Hence, the fingers of the second antenna member are near the first end of the first antenna member, which is the opposite end of the fingers on the first antenna member. The antenna members are connected at an RF feed point **320**. When connected together, the first antenna member and second antenna member form an antenna member pair which provides a horizontally polarized radiation pattern. The antenna member pair of FIG. **3** may transmit a radiation pattern having a frequency of about 5.0 GHZ in compliance with IEEE 802.11n.

As illustrated, second antenna member **322** includes finger elements **315** and **350**. Finger elements **315** and **350** opposite to and form a magnetic pair with finger elements **330** and **355** of first antenna member **325**.

The vertically polarized antenna member pair of FIG. **3** may be mounted to the surface of a PCB using tabs and shoulders. Antenna member **322** includes tabs **345** and **365** which may be received and soldered to a PCB. Above tabs **345** and **355** are shoulders **340** and **360**, respectively. The shoulder is designed to engage the surface of the PCB.

An RF signal may be fed to the vertically polarized antenna member pair of FIG. **3** via RF feed point **320**. RF feed point **320** is formed by bending a tab from antenna element **325** into an aperture of antenna element **322** and soldering the antenna members together.

FIG. **4** illustrates a top view of a horizontally polarized antenna member pair. The antenna member pair includes a first antenna member having a barrel portion **410** and connector portion **430** and a second member pair having a barrel portion **420** and connector portion **440**. Connector portion **430** and connector portion **440** are each attached to spacing member **450**. Spacing member **450** may extend along the entire depth of connector portions **430** and **440**.

The spacing member may have a uniform thickness to maintain a constant distance between the first antenna member and second antenna member of the antenna member pair. In some embodiments, the spacing member may have a thickness of about 0.03 inches wide. The spacing member material may be transparent to a radio frequency signal so that no signal power is lost, reflected, or otherwise affected by the spacing member. The spacing member may be formed by an adhesive tape that is cut to fit between and match the general shape of the connector portions.

FIG. **5** illustrates a rear view of a horizontally polarized antenna member pair. The antenna member pair of FIG. **5** includes barrel portions **410** and **420** and connector portions **430** and **440**, and tab portions **460** and **470**. Spacing member **450** extends between connector portions **430** and **440**. As illustrated, spacing member **450** may extend along the entire length of connector portions **430** and **440**.

FIG. **6** illustrates a top view of a vertically polarized antenna member pair. The vertically polarized antenna member pair of FIG. **6** includes first antenna element **322** and second antenna element **325**. First antenna element **322** includes finger elements **315** and **350**. Second antenna element **325** includes finger elements **330** and **355** and top end **310**. A spacing member **650** is located between the first antenna element **322** and second antenna element **325**. Spacing member **650** extends along the entire width of top end **310** between the two antenna elements.

FIG. **7** illustrates a side view of a vertically polarized antenna member pair. Spacing member **650** extends along the length of first antenna element **325** and **322** which is common to both elements. For example, spacing member **650** extends vertically from the bottom of spacing member **330** to the top of spacing member **350**.

A spacing member may be implemented differently in various embodiments of the invention. FIG. **8** illustrates a side view of a spacing member **805** having an upper and lower adhesive layer. Spacing member **805** may have a core **810**, an upper adhesive layer **820**, and a lower adhesive layer **830**. The adhesive layers may be applied to spacing member core **810** before the member is positioned between a pair of antenna elements.

FIG. **9** illustrates a side view of adhesive tape spacing member **950**. The adhesive tape spacing member **950** may inherently include an adhesive on an upper surface and lower surface. When used to adhere together a pair of antenna elements together, the adhesive tape spacing member **950** may be cut to match the surface of the antenna elements. In other aspects of the present invention, the antenna element pair dimensions may be designed around the thickness, desired length and other properties of the adhesive tape spacing member **950**.

The invention has been described herein in terms of several preferred embodiments. Other embodiments of the invention, including alternatives, modifications, permutations and equivalents of the embodiments described herein, will be apparent to those skilled in the art from consideration of the specification, study of the drawings, and practice of the invention. The embodiments and preferred features described above should be considered exemplary, with the invention being defined by the appended claims, which therefore include all such alternatives, modifications, permutations and equivalents as fall within the true spirit and scope of the present invention.

What is claimed is:

1. A wireless device, comprising:

an antenna array comprising a vertically polarized antenna element and a horizontally polarized antenna element that cooperate to generate a substantially omnidirectional radiation pattern, wherein each of the vertically polarized and horizontally polarized antenna elements comprises a first antenna member and a second antenna member, wherein the horizontally polarized antenna element and the vertically polarized antenna element are mounted on a printed circuit board (PCB) by respective tabs;

a first spacer element, different from the PCB, comprising an upper surface and a lower surface and displaced between the first antenna member and the second antenna member of the horizontally polarized antenna element; and

a second spacer element, different from the PCB, comprising an upper surface and a lower surface and displaced between the first antenna member and the second antenna member of the vertically polarized antenna element,

wherein the first antenna member and the second antenna member are connected at a radio frequency (RF) feed point,

wherein an antenna transmission line is connected to the radio frequency (RF) feed point, and

wherein the first spacer element has a thickness corresponding to a characteristic impedance of the antenna transmission line.

2. The wireless device of claim **1**, wherein each of the first and second spacer elements is transparent to a radio frequency signal.

3. The wireless device of claim **1**, wherein each of the first and second spacer elements is 0.03 inches wide.

4. The wireless device of claim **1**, wherein each of the first and second spacer elements comprises an adhesive tape.

5. The wireless device of claim **1**, wherein each of the first and second spacer elements further comprises an adhesive on both the upper surface and the a lower surface of the spacer element, the adhesive attaching each of the first and second spacer elements to an outer surface of the first antenna member and an outer surface of the second antenna member of each of the vertically and horizontally polarized antenna elements, respectively.

6. The wireless device of claim **1**, further comprising two radios operating in parallel, wherein the two radios generate RF signals having a same center frequency and bandwidth; and

a switching network that selectively couples the generated RF signals from the two radios to the antenna array.

7. The wireless device of claim **1**, wherein the plurality of antenna elements are vertically positioned on a printed circuit board using one or more tabs and one or more shoulders, the one or more tabs being soldered to the printed circuit board and the one or more shoulders providing a spacing for the antenna elements above the printed circuit board based on the length of each shoulder.

8. The wireless device of claim **1**, wherein the plurality of antenna elements are vertically positioned on a printed circuit board using one or more tabs.

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